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Influence of deformation mechanisms and metamorphic reactions during strain localization in the continental crust under lower amphibolite facies conditions: an example from the Gotthard massif

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Ductile shear zones are the result of the process of strain localization in the continental crust. Depending on the metamorphic conditions during deformation, strain localization is coeval with dramatic changes in microstructures, mineralogy and mass transfers, due to the interactions with externally-derived fluid. Therefore, to accurately model the mechanisms of strain localization, it is critical to identify deformation mechanisms related to the recrystallization of the quartzo-feldspathic assemblages, and to better constrain the role of metamorphic reactions during deformation. The aim of this contribution is to characterize the mineralogical, geochemical, textural and microstructural evolution of a high strain zone from the Fibbia granite, which is located in the Gotthard Massif (External Crystalline Massif, Central Alps). This variscan massif has been affected by Alpine Tertiary metamorphism and deformation under lower amphibolite facies conditions. The strain gradient is approximately a meter width. The rock texture evolves from a weakly deformed granite, toward an orthogneiss, a mylonite and a $\sim$10 cm-wide ultramylonite. The mineralogical assemblage changes from a metastable magmatic assemblage consisting of Qtz + Kspar + Pla + Bio $\pm$ Pheng $\pm$ Grt $\pm$ Ep to a fine banded texture consisting of a quartzo-feldspathic matrix, with metamorphic phyllosilicates (biotite and phengite) and garnet in the ultramylonite.

Cathodoluminescence (CL) imaging has been used to quantify the modal proportions of phases in the quartzo-feldspathic matrix in this strain gradient. More specifically, in the orthogneiss and the mylonite, CL imaging reveals a subtle layering consisting of alternating bands of quartz-rich ribbons, K-feldspars and coupled quartz- and plagioclase-rich ribbons. The texture in the ultramylonite is more homogeneous with isolated single quartz and K-feldspar grains. CL imaging has also revealed chemical zoning, as "core and mantle" texture in plagioclases. With increasing strain, modal abundance of K-feldspars decreases from 28% to 16%, whereas both micas increase from 5% to 21%. Similarly, albite evolves from 25% to 8%, whereas oligoclase evolves from 5% to 25%. Deformation mechanisms responsible for these microstructures have been studied by combining a quantitative textural analysis (CSD, SPO, grain boundary frequency and orientation - PolyLX MatlabTM toolbox; Lexa, 2005) and a crystallographic study by EBSD. Deformation mechanisms of quartz, K-feldspar and plagioclase are a combination of SGR and GBM in the orthogneiss and in the mylonite, whereas GBS is active in the ultramylonite. CPO characteristic features are still a matter of debate.

Because mass transfers occurred in this shear zone (gains of MnO, CaO, Fe2O3, P2O5 and TiO2) without volume change, thermodynamic modeling of phase relations in such open system must consider the variations of effective bulk rock composition during deformation. In this example, phase relations have been mapped using Perple_X'07 (Connolly, 2005) as a function of P, T, M(H2O) and X(bulk composition), in order to highlight the influence of subtle mass transfers on the syn-deformation stability of mineral assemblages at 500°C and 7.2 kbars. A particular attention has been paid to the role of water content on the stable assemblage and on compositions of metamorphic phyllosilicates. Water under-saturated conditions induce the stability of aluminosilicates, and should increase the Xmg in biotite and decrease the amount of tschermak substitution in phengite. P- and T-M(H20) diagram suggest that the Alpine ductile shear zones occurred under water-saturated conditions.

This study reveals that strain localization is related to the metamorphic reactions (breakdowns of K-feldspars to phengites and magmatic plagioclase to albite and oligoclase), which induce a strong decrease in grain size reduction and a switch in deformation mechanism from SGR and GBM to GBS in the ultramylonite. The good agreement between phase diagram section predictions and the observations suggest that high strain zones

are in thermodynamic equilibrium and the equilibrium volume is at least at the thin-section scale. Therefore, pseudosections can provide a forward model of the mineralogical evolution of metagranites during shear zone formation for any P-T-H2O conditions and chemical mass transfer.

References:

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